CHAPTER SIX

CONSTRUCTION SURVEYS

BUREAU OF DESIGN AND ENVIRONMENT

SURVEY MANUAL

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I. INTRODUCTION

Highway construction surveying can be divided into three categories: pre-construction, construction and post-construction. The survey crew assigned to a project is responsible for conducting all surveys required in connection with making the necessary measurements to determine pay quantities. The survey crew chief has the primary duty of making certain that the State's obligations are met with regard to furnishing the necessary stakes and information needed to construct a project.

Please Note. This chapter in the Surveying Manual has been reproduced from the Construction Manual, Section 100, Surveying Section, dated January 2001. Please refer to that manual and section for additional information if it is needed.

II. PRE-CONSTRUCTION

A. GENERAL

When a construction surveyor is assigned to a construction project he/she should carefully study and check the plans and special provisions. Any errors or omissions of significant proportion shall be brought to the attention of the project engineer, who will take the necessary steps to resolve them. The Department's position on these must be established prior to the pre-construction conference with the contractor. A thorough review not only detects errors, but also helps familiarize the surveyor with the project. He/she becomes better prepared to plan his/her operations when actual construction begins. Pre-construction plan review, note preparation, miscellaneous computations, and fieldwork are essential for a smooth operating construction project.

In order to properly construct a project, it is essential that the field layout work be done accurately. The following discussions give field personnel some guidelines to assist the staking operation. When the layout work and staking is done by the Contractor as a contract pay item, the Resident should review the Special Provisions to identify his/her responsibilities with regard to staking and checking.

B. FIELD NOTES

Field notes are the written record of pertinent information, layout, measurements and observations of the project. They should be kept according to uniform practices and conform, as a minimum, to the following general requirements:

B.1 Neatness

Use a sharp pencil of at least 3-H hardness. Avoid crowding the information and keep the book as clean as possible.

B.2 Legibility

Use standard symbols and abbreviations to keep notes compact. Use plain lettering to avoid confusion.

B.3 Clarity

Plan work ahead so that data can be clearly indicated. Do not make ambiguous statements. Line up descriptions and make sketches for clarity. Record data in a consistent way. Assume that the person who will use your notes has no familiarity with the work.

B.4 Completeness

Show all pertinent measurements and observations. Use a degree of accuracy consistent with the operation. If in doubt about the need for the data, record it. Review data before leaving the field. All entries must include:

- The date and weather conditions.
- Title of task.
- Names of all persons in the survey crew and their assignments.

The title page must be completed as the book or project is started. The District's return address must be noted on the title page in case the book is lost. The book must be adequately indexed, pages numbered and cross-referenced to contents.

B.5 Permanence

All entries should be made directly into bound books. At the completion of the project, the books should be filed as part of the permanent record in keeping with Department policy.

B.6 Accuracy

Record exactly what was done at the time it was done rather than depending on memory at a later time. Never erase in a field book. If an item is incorrectly entered, draw a line through the item and insert the corrected value immediately above. When it is necessary to add data to notes previously prepared, the additional item should be dated and initialed. Always enter notes directly into the record.

B.7 Self-checking

Notes should be kept so that the work can be checked without returning to the field. Any person familiar with the project should be able to verify the accuracy of the work from the information contained in the notes.

III. CONSTRUCTION

A. COMMUNICATIONS WITH CONTRACTOR

Harmonious relations with the contractor are essential for a smooth operating project. This condition is best accomplished through good communications between the contractor, the engineer, the surveyor and inspectors.

A.1 Pre-construction Conference

Prior to the commencement of construction activities, a conference is held with the contractor and his supervisory personnel, and the state's engineering personnel. This meeting is of particular importance to the construction surveyor since he must plan and organize his duties to conform to the contractor's planned sequence of operations so that there will be no unnecessary delays or inconveniences. The contractor will outline his working schedule and methods of operations, and discuss construction details. He should be asked to furnish the crew chief a list showing the priority of staking needs. He shall be advised that he is required to give at least 24 hours notice for any deviation from the list.

A.2 Surveyor-Contractor Relationship

It is important that the surveyor establish a working relationship with the contractor and his foremen. A cooperative foreman will make the surveyor's job much easier and greatly reduce the possibility of errors. The contractor should be made aware of the importance of maintaining traverse stations and bench marks.

B. GENERAL STAKING INFORMATION

B.1 Accuracy

Accuracy is the first essential in setting stakes. The Contractor will assume that when you have set all of the stakes they are correct. Occasionally, there are complaints from the Contractor that stakes were improperly set or that s/he incurred additional expense because of a change in grade made necessary by a mistake of the Engineer. It is a good plan to instruct the foremen and superintendents to notify you at once if at any time they consider a grade stake to be in error. This will give you a chance to check the elevation before much work has been completed.

B.2 Service to the Contractor

Service to the Contractor is another essential feature of the staking work. Do not wait for him/her to ask for stakes. Take the initiative and confer with him/her to determine the portions of the work to be staked first. Mutually agree upon the lines and grades desired, the clearances required for construction equipment, and other matters relative to the layout work. Arrange your work so you will always have sufficient stakes set ahead so the Contractor will not be delayed in starting the work.

B.3 Establish a Survey Line

Before stakes can be set, the survey line must be established and verified. It is advisable to tie in all control points, such as P.I.'s, P.O.T.'s, P.C.'s and P.T.'s to reference points outside the area of construction. Construction bench marks should be set and checked before stakes are set. All levels taken while setting stakes should be closed on bench marks before stake elevations are used. Once stakes are set they should be guarded with lath and high visibility flagging. The lath should clearly identify the stake and its use in order to avoid confusion.

B.4 Checking Work

Whatever your method, the more checking you do, the less the possibility of errors or mistakes and the fewer regrets you may have. Grade elevation, curve data, etc., should be checked before being used. All measurements, level notes, and computed distances should be rechecked frequently. Check with the plans. It is dangerous to try to check from memory. It is embarrassing to all concerned when a bridge, for example, is built to the wrong elevation, or with the grade reversed, or when the distance between bridge seats is too short or too long. These things have happened in the past, but they will not likely occur if the work is carefully checked.

C. SETTING AND RECORDING OF LAYOUT STAKES

C.1 Staking Methods

The field methods outlined below are not given with the thought that every Resident shall follow the same procedure in his/her instrument work, but rather that each is a good method to use if the Resident is in doubt as to how to proceed. They should be read carefully, however, as they may suggest some point of brevity or additional accuracy, or may clarify the fundamentals in each problem.

A standard method of staking should be followed but may be varied to meet topographical conditions, type of construction, equipment used, and the Contractor's preference. This is a convenience to contractors who work in more than one district, and also reduces the chance of confusion and misunderstanding between engineers in the field and the district office.

C.2 Fieldbooks

All fieldbooks must contain the task description, weather, date when work was actually done and names of persons performing the work. The Resident should keep a complete legible record of all stakes set. The description and elevations of all new bench marks and the new ties for all points should be recorded and completely described. Grade changes and other changes from the original design should be recorded and carefully described. All records must be clear and complete so that any stake can be replaced easily, at any time, with a minimum amount of effort. It should never be necessary to rerun several thousand feet of line to replace one or two stakes.

C.3 Prepare in Advance

It is essential that fieldbooks containing the necessary grades, sketches, line ties, bench marks and other data be prepared in advance. Delays and inconvenience result if it is necessary to refer to the plans often for layout information. Notes and sketches should be independently checked. The books should contain grade elevations at the intervals required, survey line ties, bench marks, curve data and any other data required for frequent use.

D. STAKING CURVES

D.1 Check Plans

The curve data listed in the plans should be carefully checked, including the P.I.'s and the P.O.T.'s. You will encounter considerable difficulty in running in the curves if the intersection angles do not check and new curve data must be calculated. Usually, this is done when verifying the transit line. Any discrepancies found, which you do not know how to correct, should be discussed with your Supervisor.

If practical, reestablish P.I.'s and the necessary P.O.T.'s. Record the intersection angles, reference all P.I.'s and P.O.T.'s and record their stations and reference points.

D.2 Setting Stakes

Where practical, set up on the P.I. having as a foresight and backsight the P.I. or P.O.T. on either side of the P.I. over which you are set. Using the transit for line, measure accurately the tangent distance in each direction and set hubs at the P.C. and P.T. of your curve. The station number of the P.C. is the station of the P.I. minus the tangent distance. The station of the P.T. is the station of the P.C. plus the curve length.

Before running curves, the notebook table of stations, deflection angles and chord lengths (including chord corrections if needed) must be set up and checked. After the P.C. and P.T. are established, set up over the P.C. and proceed to run in the curve. Offset the stakes the proper distance each way from the centerline. Curve data from computer programs should be spot-checked.

It is often necessary to run curves in the reverse direction to that of the stationing. On long curves where the view is obstructed, it is necessary to turn at one or more points on the curve.

Curves should close within about 0.25 feet per 1000 feet of length. The error of closure should be proportionally distributed over sufficient length so that the eye can detect no break in the alignment. On flat curves having external distances of 2 feet or less, it is faster to run in the curves by tangent offsets.

E. STAKES FOR BRIDGES

E.1. General

Prior to staking a bridge, plan dimensions and elevations should be checked. It is extremely important to check the elevations of the bottom of the footing by working down from the profile grade line at each pier and abutment, using plan dimensions, beam depths, etc.

The entire structure should be staked before construction operations begin. Remember that the stakes you set are going to be used over and over again from the time you stake the footing excavation until the bridge is finally completed. As the work progresses, you will not be able to see from one stake to another as you did in the beginning and you should give this fact consideration when staking the bridge. It is better to have a few extra points than not to have enough. A substantial number of stakes located out of the way of Contractor's equipment and material should be used. At least three stakes on each line should be set each way from the site. Check all elevations and be sure all the stakes are protected, well referenced and clearly identified.

When you have completed the staking, notify your Supervisor so that someone assigned by your office may make an independent check of your calculations and layout work before the Contractor starts work on the structure. When the layout work and staking is done by the Contractor as a contract pay item, the Resident Engineer should review the Special Provisions to identify his/her responsibilities with regard to staking and checking.

Thorough and accurate layout work, checked by an independent party, is a must for structures, however, the checking should not stop here. It is important to have positive control points on each pier and abutment so, as the bridge cone embankments are being constructed, instrument checks can be made easily to determine any movement. Be particularly careful when the embankment toes out near the bottom of tall piers, as frequently happens with railroad structures.

Each stake set should be recorded, as well as all elevations that are given to the Contractor. It is good practice to sketch each feature of the bridge and show the stakes with the references and distances of their respective locations. See Figure 6.1, page 6-25 for a "SAMPLE STAKING DIAGRAM". It is also a good practice to share staking diagrams and information with the Contractor to avoid possible future disputes.

E.2 Triangulation and E.D.M. System

On multiple or long span bridges, especially bridges with steel superstructures where the width of the stream or other conditions prevent direct measurements, the location of abutments or piers must be measured with an electronic distance measuring system (E.D.M.) and/or by triangulation methods. Precise methods are required in such work and are necessary for long structures. The E.D.M. system or triangulation method should be supervised by the Resident in charge of the work.

In triangulating locations for long bridges, concrete monuments, or large stakes set deep and cut off near ground level should be used. Remember that the location may be affected by freezing and thawing, floods, driftwood and ice. Measurements should be corrected for temperature and a scale should be used to set the pull that is standard for the tape that is used. Long measurements should be made with an electronic distance-measuring device. When possible, intersection lines should be set for each pier at an angle of 45 degrees with the base line, and the base line should extend both sides from the centerline of the bridge. The intersection lines should be run out to points above high water on both sides of the river so that the locations can be set when the low ground is flooded. Angles should be set using repetition and should be checked by measurements. Guard stakes should be placed at each hub and the layout should be marked so that no confusion may result.

In some cases it is desirable to establish a low water and a high water base line. A base line that is above low water elevation can usually be placed nearer the bridge site and will be found very convenient.

E.3 Span Length

In staking the abutments, an allowance must be made for any anticipated deflection of the abutments so that the span length after deflection will be as shown on the plans. Theoretically, the amount of deflection can be figured, but practically it is somewhat indeterminate because of the variable conditions of the footings and backfill. It is assumed that the pressure of the backfill will move the top of a closed abutment or a concrete pile abutment horizontally 1/16 of an inch for each foot of height measured from bridge seat to bottom of footing. For open abutments, the assumed movement is 1/32 of an inch per foot.

In the case of a single span, if a correction is necessary for the deflection of the abutments, add the total deflection of both abutments to the span length shown on the plans to get the length for locating the abutments. In case of a multiple span bridge, add the deflection of one abutment to the length of the end span only.

E.4 Locating Centerline

Care must be exercised in locating the centerline of a structure. The centerline of roadway and structure are not always the same. From the road plans or original survey notes, establish at least two P.I.'s or P.O.T.'s in each direction from the bridge and tie them in permanently. This should be done to ascertain if the intersection angle in both directions from the bridge is correct. If the P.I. or P.O.T. in each direction cannot be seen from the bridge, establish a P.O.T. on each side of the bridge and as close to the original P.I. or P.O.T. as possible. Place a permanent hub on centerline each side of and as close to the bridge as possible without interfering with the Contractor's operation. The Contractor should be requested to assist you by keeping equipment and materials clear of the line between these hubs. When possible, a permanent foresight should be set on the centerline of the bridge as high as the ground permits. It should be possible to set centerline from either side of the stream.

Establish hubs on centerline of bearing or back of abutment and on the centerline of each pier. These hubs should be heavy stakes and nails should be used for line. It is very important that the Resident and Contractor clearly understand and agree on what lines are staked. You may provide the Contractor with a sketch of all lines and stakes set.

Establish permanent bench marks close to the bridge. The bench marks on the plan or original survey should be checked before establishing your benches at the bridge site. Transfer your bench marks to permanent concrete or piling on the structure. Use the bench marks established on the structure for the remaining work. Do not set temporary bench marks on newly constructed embankments since they may settle. Be assured that your transit/theodolite and level maintain proper adjustment.

E.5 Staking Abutments

Set up and turn the skew angle at the hub that is set on centerline of bearing or the back of abutment at the centerline of structure. On this line set a hub close to the bridge and two at distances of 200 feet and 400 feet from the centerline of structure. If this cannot be done, set them as far as possible from the bridge. Check the skew angle by repetition before proceeding.

E.6 Staking Piers

From the hubs established on centerline of the structure turn the skew angle and set additional hubs in each direction, the same as you did for the abutment. Care must be exercised in establishing this line since the centerline of bearing and centerline of pier are not always the same. The vertical alignment of piers should be monitored with a transit/theodolite during concrete placement.

Measure the distance from the centerline to each hub and record it. Measurements for bridge layouts are often made on rough, uneven ground. It is necessary to have the chain horizontal and to use a plumb bob for accurate measurements on such terrain. Check your measurements. Whenever possible, physical measurements should be made as the work progresses.

E.7 Staking Cofferdams

In fixing the location of cofferdams, it is usually best to give the Contractor only the center of the pier and the centerline of the structure. The Contractor can then determine the width and length, knowing what allowance is needed for footing forms, drainage outside the forms, size of walers and struts, etc. Cofferdams in deep water may be located by triangulation. Proper alignment may be secured by placing marks at the intersection of the centerlines with each edge of the frame to be spotted and moving the frame until both marks are on the transit line.

E.8 Staking Footings

Check carefully the elevation of the bottom of the footing as shown on the plans and compare it with the distance below the actual streambed that you find. If there is a discrepancy of a foot or more, consult you Supervisor.

Keep the Contractor informed at all times as to the work you are doing, and give him/her a record of all stakes set. When the neat line forms of the footing are in place, the top of the footing should be established by setting nails with an instrument at convenient points around the footing. When footings are too deep to set elevations directly, turns may be established by measuring down to a nail from a point of known elevation.

E.9 Miscellaneous Elevations

After the forms for either an abutment seat or pier cap have been built, grade points for the bridge seat elevations should be set with an instrument. The level circuit for setting the bridge seat elevations should be checked by using one of these set elevations as a turning point. Elevations at tops and wings should also be set with an instrument. Seat elevations should be checked after the concrete is placed. Bridge seat elevations should be checked by subtracting the deck thickness, minimum fillet, beam and bearing heights from the finished deck elevations before laying out the bridge seat elevations in the field.

On steel truss spans supported by falsework, it is essential that each panel point of support be set at the exact camber elevation before any connections are made.

F. STAKES FOR BORROW PITS

Although setting stakes and running cross-sections for a borrow pit seem to be a simple matter, it is, nevertheless, a matter that calls for more than ordinary accuracy. Inaccuracy or lax procedures anywhere from start to finish will almost certainly result in confusion and possibly in a dispute with the Contractor over the volume involved.

If the borrow pit is furnished by the State, it should be staked before construction starts so that the Contractor will not encroach upon private property. If the pit is furnished by the Contractor, s/he should obtain the necessary approval and show you the location of the boundaries in sufficient time to take cross-sections.

When the pit is furnished by the State, establish its location from the plans. For pits adjacent to the right-of-way, it is often convenient to use the centerline as a base line, if on a tangent. Usually the base line should be chosen parallel to the long dimension of the pit, which means that it may not always be parallel to the centerline of the roadway. In all cases, the base line must be readily reestablished or preserved until all work is finished. If the centerline is not used, the base line chosen should be tied accurately. Base lines should always be straight lines regardless of the shape of the borrow pit. It is often convenient to locate the base line in a fence line or other location where hubs on the line will not be destroyed. The base line should be referenced to points which will remain after borrow is completed.

See Figure 6.2, page 6-26 for a typical borrow pit layout.

F.1 Stakes for the Base Line

The drawing indicates the pit is parallel to the centerline. The base line is parallel to the centerline and is as close to the borrow pit as it can conveniently be placed without being disturbed by the Contractor's operations. From the base line run a parallel line on the opposite side of the borrow pit and reference it, locating it close to the pit (perhaps within 10 feet) but out of the way of the

Contractor's operation. Use an instrument to turn angles and a steel tape or an EDMI for all measurements, and be sure to have the lines on each side of the borrow pit well hubbed and referenced. Base line stakes should be marked with the station numbers and driven solidly in the ground. Borrow pits often stand over the winter season before borrow is completed. You must be able to reestablish any line easily, at any time, at its exact original location.

If the boundary of the borrow pit is a curved line, this curvature must be taken into consideration in taking cross-sections and computing final quantities.

F.2 Stakes for Cross-Sections

The base line and its parallel line on the opposite side of the borrow pit are marked lines "A" and "B". The borrow pit limits as staked out are to be visible, carefully referenced, and accurately measured from the centerline.

On line "A" set stakes at 25 foot intervals (or not more than 100 feet) and at all breaks in the grade. Record the distance to each stake. Set a corresponding stake on line "B" by turning an angle of 90 degrees from line "A". When placing stakes on the original ground surface, keep in mind the contour of the finished pit and take enough points to cover breaks in both the original and final ground lines. Do this along the base line and its parallel and along each cross-section. It is often convenient to use a range pole or flag set as a foresight at the far end of the sections to be taken, to ensure that the sections are taken on a straight line and in the proper location.

F.3 Original Cross-Sections

Cross-sections must be taken before excavation starts. Establish a permanent bench mark close to the borrow pit, using the plan datum if possible. Take readings along each cross-section line established between line "A" and "B". Take the readings often enough to get all the breaks in the grade on each section. Measure the distance to each point accurately. Have the cross-section readings extend several feet outside of lines "A" and "B". It is a good idea to take a few cross-sections beyond the ends of the borrow pits also, as it may be necessary to enlarge the pit after excavation starts. Be sure to check cross-section distances against stakes previously set in the base line and offset line. Close the level circuit on a bench mark of known elevation.

F.4 Final Cross-Section

After the excavation is completed and the borrow pit shaped, you should recross-section the pit at the identical locations used previously. In addition, cross-sections should be taken at the breaks between the back slopes and level parts of the pit. Original sections at these points may be interpolated. Usually, it is not possible to determine such points in advance. The recross-sectioning should be done as soon as possible. It may be necessary to take cross-sections before the borrow pit is leveled off, if the Contractor delays this finishing very long, because of the danger of the contour of the pit being changed by heavy rains. It is convenient to check borrow pit drainage in connection with the final cross-sections.

F.5 Pit Subject to Overflow

If the borrow pit is subject to overflow and the Contractor suspends work for any considerable length of time, the pit should be cross-sectioned immediately after work stops. If overflow occurs, the pit must again be cross-sectioned before work starts as alluvial deposit may appreciably affect the quantities.

F.6 Computations

Plot your notes and compute the volume used on the project by the Contractor. If computations are to be made in the District Office, retain a copy of your cross-section notes. It is a good idea to spot check the cross-sections yourself to make sure they close.

G. STAKES FOR GRADING

Usually, three sets of stakes will be used for controlling a construction contract; (A) Right-of-way, Control, and Structure (b) Preliminary Grade and (c) Finish Grade.

Before you start setting stakes, consult the Contractor to learn whether your accustomed method will suit his/her convenience. After you have come to an agreement, make a note of it in your fieldbook, and make certain that the Contractor understands just what method of staking you will use, at what points stakes will be set, and how they will be marked. It is best to give him/her this information in writing as this may avoid a future controversy. A 5 foot offset, if possible, will permit satisfactory distances from the toe of slope or edge of ditch to permit the Contractor sufficient workroom for his/her operation. Each cut or fill entered on the grade stakes should be recorded in the fieldbook. Prior to the contractor beginning dirtwork operations, the original ground elevations should be spot checked for accuracy.

After the earthwork is roughed in, the Contractor will request a line of stakes, usually down the centerline of the roadway, to establish the completed crown grade. This line of stakes should be set with an instrument and the grade shown as requested by the

Contractor. When the roadway is built as close to grade as possible with the previous stakes, it will then be necessary to set line stakes and paving stakes at 50 foot intervals. Closer intervals are required on a tight horizontal or vertical curve. These stakes should be of hardwood, preferably a 1-inch x 2-inch or 2-inch x 2-inch size, or metal of sufficient length to penetrate the grade far enough that the movement of equipment will not cause variations once the grade is established.

The subbase and pavement can be built from these paving stakes. The Contractor should be cautioned against destroying the stakes. If this condition is encountered, the Specifications permit a fee that can be assessed for replacing the stakes.

G.1 Slope Staking

Before the Contractor begins earthwork operations, it may be necessary to place slope stakes to define the toe of the slopes for ditches and/or fill areas. It is important to consult with the Contractor to determine what information will be necessary. Usually the stakes indicate the station location, cuts or fills for roadway and ditch, rate of slopes and the offset distance from the stake to the toe of slope.

Because of the large amount of information required, the Contractor should provide pointed 1-inch x 6-inch boards (paddles) to record the information.

The actual layout is a trial and error procedure. It compares the actual distance of the stake to the theoretical calculated distance. The stake distance is then adjusted until the actual and theoretical distances coincide. Different systems are used depending on personal preference. The difference is the point of reference where the calculated distances are based. The Resident should contact their supervisor well in advance of needing the slope stakes if training or guidance is needed.

G.2 Balance Points

A prominent marker should be placed at each earthwork balance point.

G.3 Curve Superelevation

Review the curve data and typical sections shown on the plans for superelevation rates, transition lengths, and points of rotation. In some instances, this superelevation may create drainage problems, especially in flat terrain and with wide pavements. Review the curve data shown on the plans for superelevation limits and rate.

Superelevation within the limits of villages or cities is designed for the slower speed required and is, therefore, generally less than that found in rural areas where higher speeds prevail. The difference in superelevation is, as a rule, the result of the difference in speeds, although there may be specific instances where good judgment or local conditions call for some modification of our standard practice. If you have any doubts as to whether you should follow our standard practice, discuss the matter with your Supervisor.

H. STAKES FOR ENTRANCE CULVERTS

H.1 Location

All entrance culverts should be set to match the roadway ditch, both in line and grade.

H.2 Staking

The only stakes that are necessary to be set for an entrance culvert are two stakes on the centerline of the culvert barrel. Mark on these stakes the cut to the ditch flow line.

H.3 Elevation of Headwalls

If headwalls are built, it is essential that the top elevation of the two headwalls be made parallel to the grade of the shoulder, even though the gradient of the ditch is not the same as that of the pavement.

I. STAKES FOR ACROSS-ROAD CULVERTS

I.1 Location

Prior to staking out an across-road culvert, determine whether the location as shown on the plans will fit the channel to the best advantage. See the following section “How to Check Plan Pipe Culvert Lengths”. If you think the culvert line or grade should be relocated or the skew angle changed, take the matter up with your Supervisor. Channel locations should not be revised without approval from your Supervisor.

I.2 Staking

The centerline of the culvert barrel should be staked first by placing a stake on the centerline not closer than 5 feet outside of each headwall. Nails should be set in the stakes giving the exact line. The cut to flow line should be marked on the stake, measured from the top of the stake. Also, always check the plan length for accuracy.

I.3 Elevation of Headwalls

After the forms are built, it is sometimes necessary to set the elevation to be used for the top of headwalls. Give the elevations on the forms at which to set the chamfer to the Contractor. Remember that the tops of the headwalls must be parallel to the grade of the centerline of the roadbed.

J. HOW TO CHECK PLAN PIPE CULVERT LENGTHS

When checking a culvert for length, the following information is given:

W = Right angle distance from centerline to shoulder point. This may be found on the typical section sheet or from cross sections.

K = Difference in elevation between centerline elevation and shoulder point. Also given on typical section sheet (Special case superelevated curves).

Centerline Elevation: Given on plans or may be calculated.

Invert Elevation: The flow line of pipe culvert at inlet or outlet end. Given on plan sheet and cross-sections.

N = Slope: Defined as number of feet horizontal per one foot vertical at right angle to centerline.

Skew angle = (alpha): The angle between the centerline of the pipe and a perpendicular line to the centerline of the roadway.

C = Distance from the top of the headwall to the invert elevation found under Standard or Special Headwall Sheet listed for particular pipe. (See typical pipe data below).

t = Thickness of Headwall. (See typical pipe data below).

TYPICAL DATA GIVEN ON PLAN SHEETS FOR PIPE CULVERTS

Sta. 1395 + 00
Double Pipe Culvert Type 2A
RCCP CL II 36" 338 Linear Feet.
Headwalls Standard 2102-D-36-2
Both Headwalls:
5.00 Cubic Yards CL "X" Concrete (Headwall)
230 Lbs. Reinforcing Bars (Headwall)
D.A. 40AC
Method II installation

Sta. 1286 + 54
Pipe Culvert Type 2A
RCCP CL II 36" 192 Linear Feet.
(Left 94' & Right 98')
Headwalls Standard 2051-DS-36-2
Both Headwalls
5.6 Cubic Yards CL "X" Concrete
150 Lbs. Reinforcing Bars
Skew Angle = 25 degrees
D.A. = 22AC

J.1. Right Angle Installation (See Figure 6.3, page 6-27 For Diagram)

The procedure is as follows:

Right angle culvert (Skew angle of zero (0))

Total Length $L_T = 2W + L_A + L_B$

For L_A or L_a
Elevation C = C_L Elevation – K
Elevation D = Invert Elevation (A or B) + C
M = Elevation C – Elevation D
$L_{AB} = N(M_{AB}) + t$

$L_T = 2W + L_A + L_B$

Example: Right Angle Culvert Station 10 + 00

W = 22 feet, K = 1.00 foot, C = 3.00 feet, t = 0.5 feet, N = 3:1

CL Elevation = 150.00, Invert Elevation A = 100.00 feet, Invert Elevation B = 105.00 feet

L_A Elevation C = 150.00 – 1.00 = 149.00
Elevation D = 100.00 + 3.00 -= 103.00
M = 149.00 –103.00= 46.00

L_A = t +NM_A = 3(46.00) + t = 138.00 + 0.5 = `138.5

L_B Elevation C = 149.00
Elevation D = 105.00 + 3.00 = 108.00
M = 149.00 – 108.00 = 41.00
L_B = NM_B + t = 3(41.00) + 0.5 = 123.00 + 0.5 = 123.5

L_T = 2W + L_A+ L_B = 44.00 +138.5+ 123.5 = 306.00 feet.

J.2 Skewed Pipe Culvert (Equations) (See Figure 6.4, page 6-28 for Diagram)

Assume Y_A is correct.

X = Y_A sin α

Sta. X = Sta. of Pipe $\pm$ X

Calculate Centerline Elevation of Station X

Calculate shoulder break elev. of point "a" = Centerline Elev. Station X-K = Elev. C

Elevation D = Invert Elevation A or B + C

L_A = N (Slope) x M (Elevation C – Elevation D) + t

$$Y_A = \frac{L_A + W}{\cos \alpha}$$

Does Y_A (calculated) = Y_A assumed)?

If NO, then a new Y_A must be assumed and the procedure repeated.

Example: Skewed Culvert

Same data as above with Skew Angle = 45 degrees RT Forward

Mainline grade given: Y_A = 220

Y_B = 200 (Assumed correct but not checked for this problem – Check left side only.)

Y_A = 200 (assumed correct)

$X = Y_A \sin 45°\alpha = 220\ (.70711) = 155.56$

Station X = 10 + 00 – 155.56 = 8 + 44.44

Elevation Station X = 150.00 – 155.56 (1%) = 150.00 – 155.56 (.01) = 148.44

Elevation C = 148.44 – 1.00 = 147.44

Elevation D = 100.00(Inv. El.) + 3.00 = 103.00

M = (Elev. C) – (Elev. D) = 147.44 - 103.00 = 44.44

L_A = t +NM = 3.00 (44.44) + 0.5 = 133.82

$$Y_A = \frac{133.82 + 22}{\text{Cos } 45°} = \frac{155.82}{.70711} = 220\text{, therefore, OK}$$

K. STAKES FOR PAVEMENT

K.1 Alignment and Grade

The essentials of a good paving section, alignment and grade, should be kept in mind continually when setting stakes for the work.

K.2 Fieldbook

Before setting any stakes, you should prepare your fieldbooks, check all computed grades shown on the plans as well as your calculated grades for other points. If the proposed pavement is to tie into existing pavement, the existing pavement elevations should be checked. Review the District Computer Programs for assistance. In addition to normal grade stake elevations, it is desirable to include the following data in your fieldbooks:

- Elevations of each edge of pavement on superelevated curves and on superelevated transitions at ends of curves, at 50 foot intervals;
- Ties to all survey line control points, points of curve and tangent, bench mark elevations and locations;

- Tables of curve deflection angles and chords;
- Tables of offset from survey line to form stake line when required;
- Your return address (in case book should be lost).

It is a convenience, and will save time, if all necessary information from the plans is carefully transferred to the fieldbook.

K.3 Notes for Setting Grade Stakes and Stringlines for Automatic Grade Control Equipment

Automatic grade control equipment automatically transfers the accuracy of the predetermined plane to the subgrade, base or surface, resulting in a neat line profile.

Automatic grade control equipment makes the transfer by the use of sensing units which contact the stringline on either side of the grade.

Normal Stringline Setting. The Contractor will usually set metal stakes which are 42 inches long and are driven into the ground, normally at 50 foot intervals along one side of the roadway when using a machine equipped with automatic slope control or along both sides of the roadway when using a machine with sensors installed on both the right and left sides of the machine. The metal stakes are set to the hubs (grade stakes set for the roadway) for both dual lane and single lane machines. On superelevated sections and ramps, the metal stakes should be set at 25 foot intervals to gain a greater degree of accuracy.

Factors to Consider for Stringline Installation. The following factors should be considered before any preparation for setting the stringline is started, to determine the most feasible location for the stringline:

- Other work that may be performed either between the stringlines, when two are used, or along the shoulders.
- The amount of material to be wasted near the stringline and the disposition that will be made of the material.
- Obstructions along either side of the roadway.
- The limit of the autograde sensor arm supports.
- The percent of fall from the centerline of the roadway to the hubs or edge of pavement.

Location of the stringline may vary with each section of the roadway to be worked, due to supers, crowns and offsets. Each section should be evaluated separately to determine the proper location or position of the stringline.

Stringline Hubs. Accurate operation of automatic grade control equipment depends on the correct installation of the stringline and the precise setting of the line and grade hubs. Considerable effort can be saved in the initial engineering if the Resident and Superintendent discuss the proper offset distance of the hubs and the specific machine to be used for each operation.

For autograde equipment operating from two stringlines, two sets of grade hubs are needed to work the roadway from the initial subgrade to the finished slab. See Figure B, page 6-29.

For autograde equipment equipped with only one grade sensor and an automatic cross slope grade control, only one set of grade hubs is needed. See Figure A, page 6-29.

Each stringline must be set at a constant distance from the roadway centerline or a theoretical edge of the pavement. Each stringline must also be suspended at a constant height above the plane passing through the lower corners of the proposed slab.

L. COMPUTER APPLICATIONS

The Resident should be aware of and optimize the use of the department's computer services. The following programs are available at the District level.

L.1 Field Control

Coordinate Geometry: An ICES subsystem capable of solving geometric problems, determining coordinates for triangulation and locating control points by station/offset values.

Roadway Analysis and Design System: An ICES subsystem capable of computing earthwork quantities, plotting cross-sections and producing printed tables of slope stake locations.

Offset Line Elevations: This program is capable of producing tables of offset line elevations for paving stakes. These tables may optionally be printed on fieldbook size pages.

Circular Curve Deflection Angles: Produces, in tabular form, deflection angles for staking of circular curves in the field.

Three Point Problem: Determines plane coordinates for a point based upon sightings of three non-collinear points whose coordinates are known.

Bridge Deck Elevations: Provides a listing of bridge deck elevations along each beam of a bridge and can adjust these elevations to reflect dead load deflections.

L.2 Field Quantities

Bridge Fillet Quantities: Computes fillet quantities, based upon plan values and field measurements.

Borrow Pit, Embankment and Excavation Computations: Computes cut and/or fill, along with end-area for each cross-section, as well as accumulated totals. Plotting of cross-sections is available

Reinforcing Steel Quantities: Tabulates total weight of reinforcing steel.

L.3 Quality Control

PCC Proportioning: Designs concrete mix for user specified material and specific gravity.

Bearing Tables for Pile Hammers: Provides a table of bearings versus blows-per-foot. Also computes blow-per-foot to reach a specific bearing.

Slope Stability Analysis Series: These programs analyze the stability of slopes using various test methods.

IV. POST CONSTRUCTION

A. FINAL MEASUREMENTS

Final measurements for pay quantities should be made concurrently with construction operations where feasible. This procedure results in greater accuracy and reliability. Naturally, some items can only be checked after construction is completed.

A.1 Items Measured During Construction

The following items are examples of those that should be measured immediately after constructed:

- removal items
- sub-cuts
- storm sewers
- conduit
- buried cable
- clearing and grubbing

A.2 Items Measured after Construction

- fencing
- guard rail
- turf establishment
- structure length
- curb and gutter
- sidewalks
- bridge approach panels

All measurements for final payment made by the survey crew must conform to the requirements in the document “Standard Specifications for Road and Bridge Construction” adopted January 1, 1997.

A.3 Final Cross-Sections

Final cross-sections are used for the computation of final pay quantities. Cross-sections should be taken at the same station as the original was taken. This eliminates any need for interpolation of an original at the new station.

A.4 Structures

The survey crew should measure drainage structures (catch basins, manholes, etc.) at the time of placement. Final elevations and locations will be required.

A.5 Final Plans

The original plan sheets must be corrected to show any changes and additions made during construction. All corrections or changes shall be noted on the plan sheets. No original details should ever be removed from the plan sheets.

The following list provides some of the information that must be checked, corrected and added to the original plan sheets:

- Horizontal and vertical control
- Location, dimensions, and elevations of drainage structures. All of these should be field checked.
- Changes in typical sections
- Horizontal alignment (including curve changes and control point ties
- Profile grade
- All underground units (cable, conduits, pipe, etc.)

B. MONUMENTATION

The construction surveyor should be in charge of as much of the post construction monumentation as possible.

B.1 Final Alignment

Every effort should be made to monument the final alignment prior to the project being opened to traffic. All P.I.'s shall be monumented, or if inaccessible the adjoining tangents shall be monumented. P.C.'s and P.T.'s should be monumented.

B.2 Right of Way

The right of way should be monumented and marked prior to construction and maintained throughout. However, if the right of way must be re-monumented, it should be done under the supervision of an Illinois Professional Land Surveyor since it involves land surveying.

B.3 Bench Marks

During the course of construction, the bench mark and the temporary bench mark status changes. Many are destroyed and many are established. At the end of the project, a bench list should be made tabulating all remaining bench marks and temporary bench marks.

B.4 Traverse Stations

On projects employing the Illinois State Plane Coordinate System, efforts should be made to perpetuate the control stations after completing construction. All remaining control stations should be shown on the final plan sheets.

SAMPLE STAKING DIAGRAM

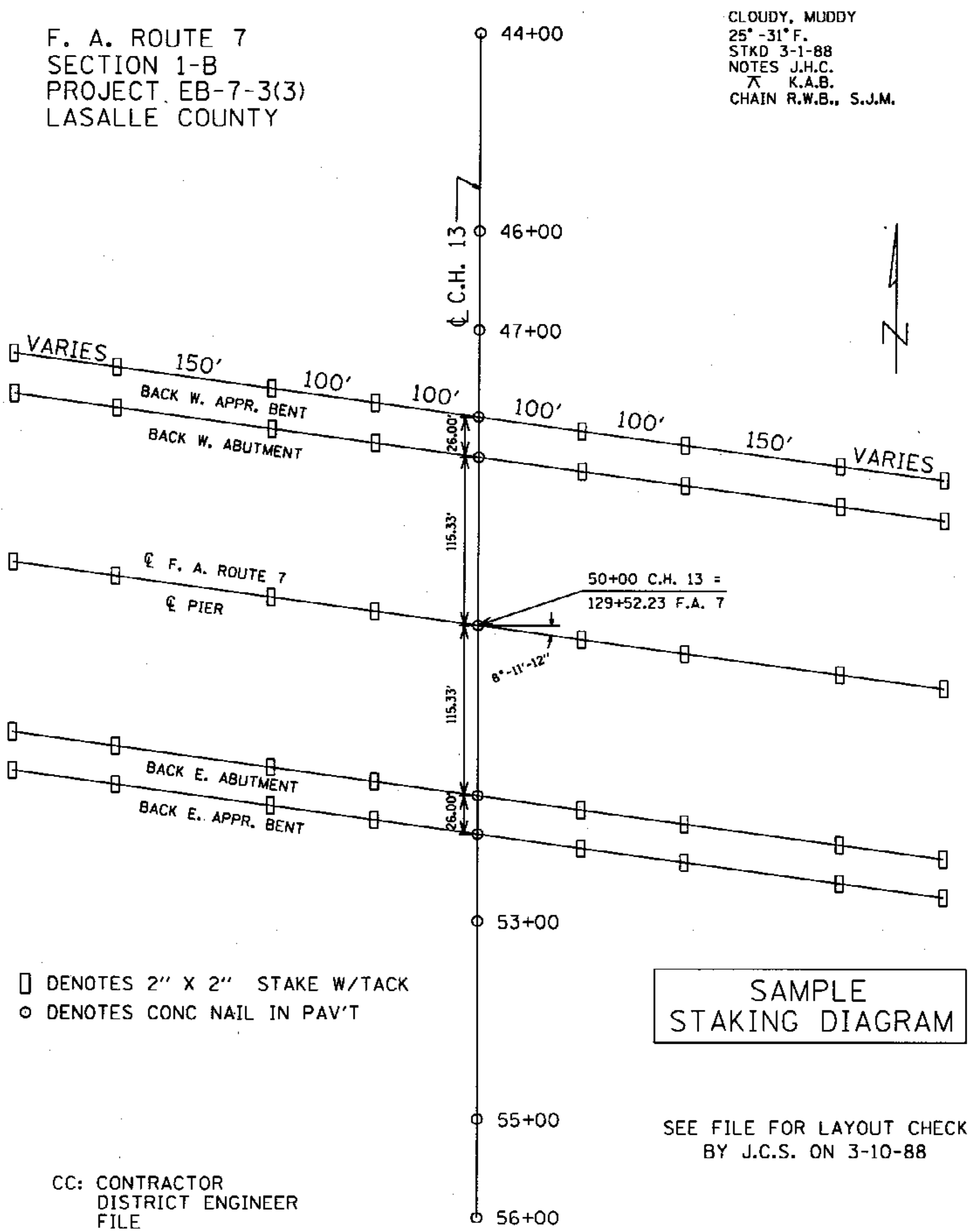


Figure 6.1

STAKES FOR BORROW PIT EXAMPLE

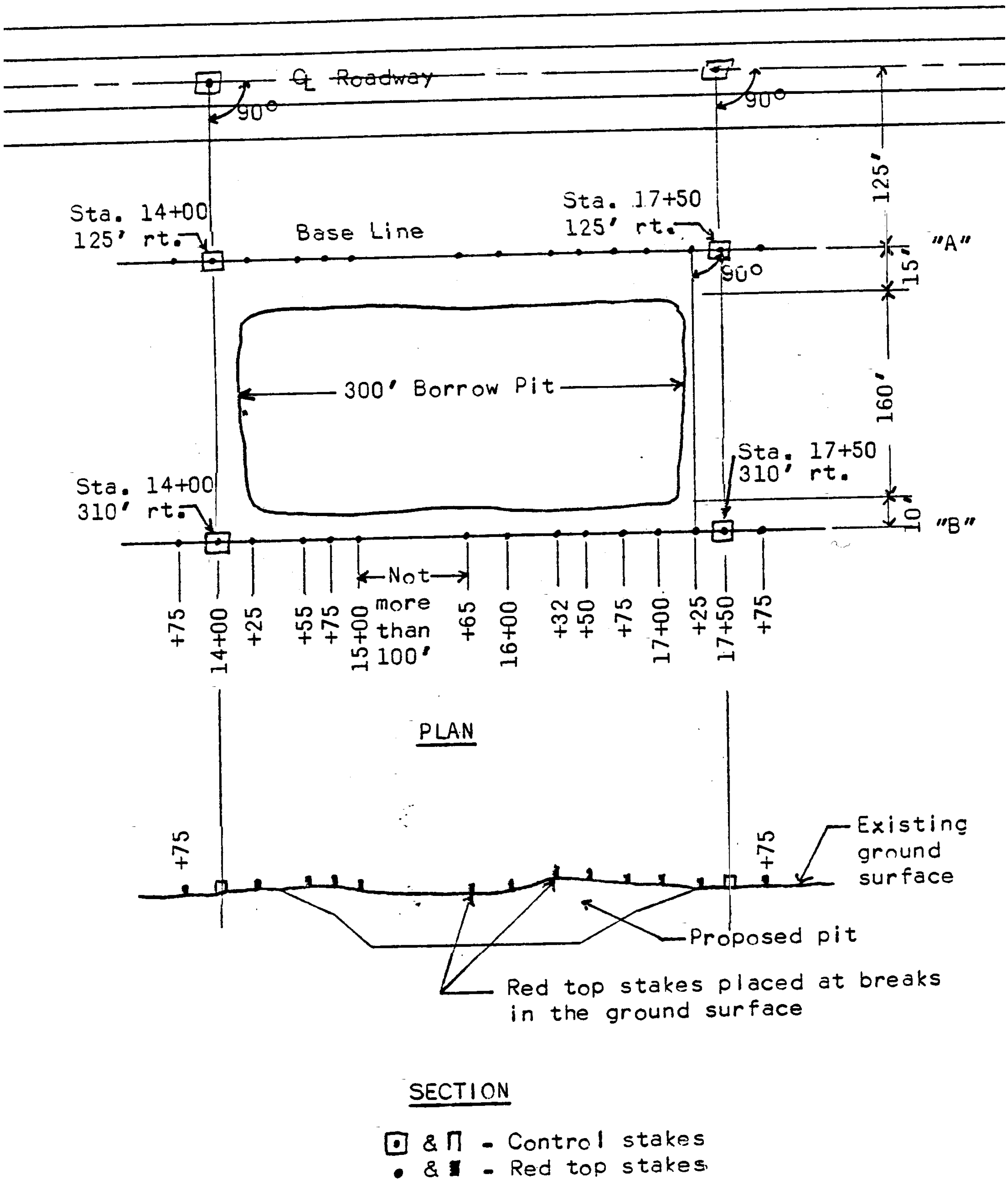


Figure 6.2

RIGHT ANGLE INSTALLATION

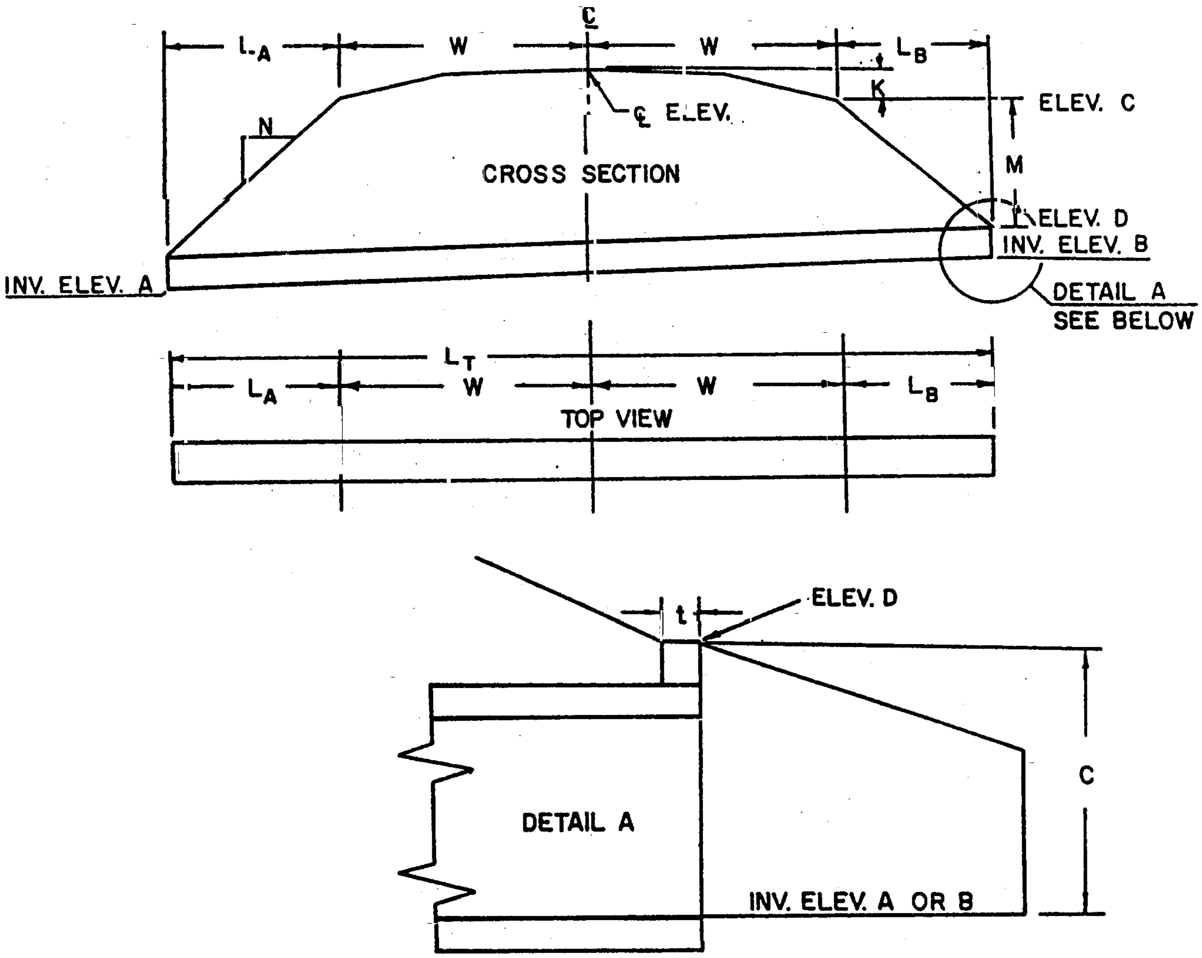


Figure 6.3

SKEWED CULVERT INSTALLATION

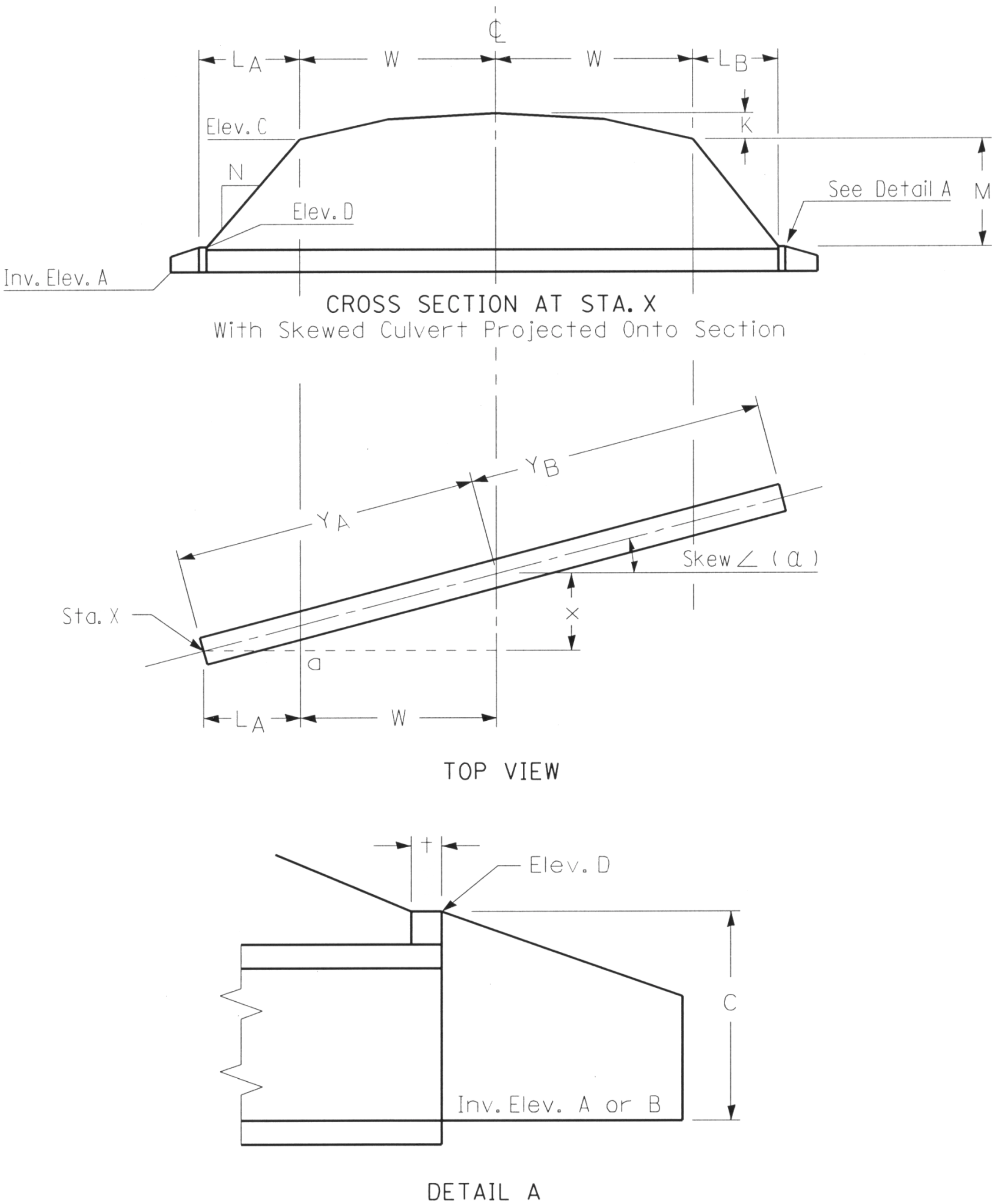
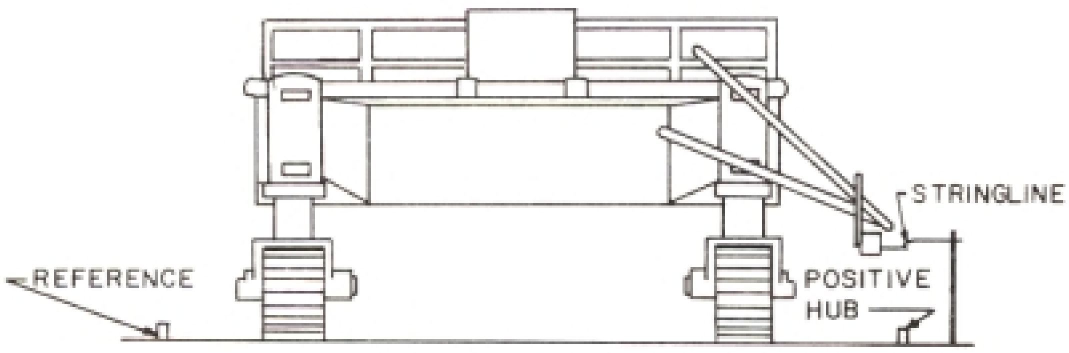


Figure 6.4

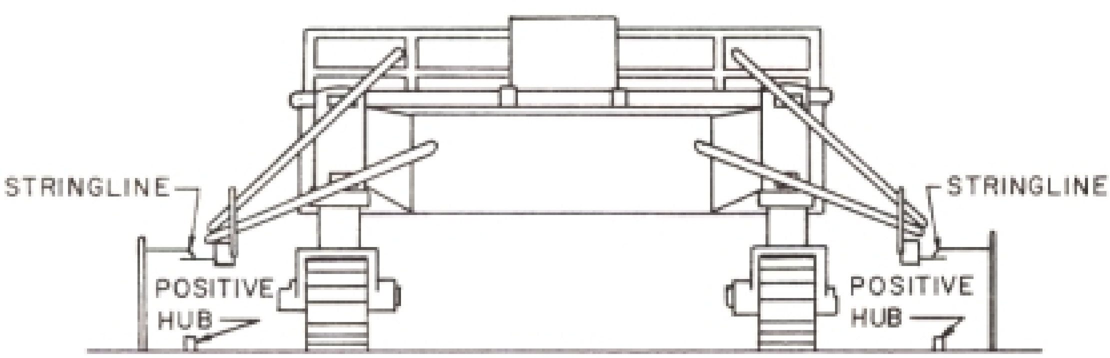
AUTOGRADE WORKING FROM 1 POSITIVE HUB,
WITH CROSS SLOPE SYSTEM



NOTE: ALL AUTOGRADE EQUIPMENT EQUIPPED WITH CROSS SLOPE SYSTEM NEEDS ONLY ONE SET OF POSITIVE HUBS

FIGURE A

AUTOGRADE WORKING FROM 2 STRINGLINES,
WITH 2 POSITIVE HUBS



NOTE: WHEN OPERATING FROM TWO STRINGLINES, TWO SETS OF POSITIVE HUBS ARE NEEDED

FIGURE B